Challenges and Alternatives in Tsunami Water Levels Processing in NOAA/NCEI Global Water-Level Data Repository

George Mungov[1,2], *Paula Dunbar*[1], *Kelly Stroker*[1,2], *Aaron Sweeney*[1,2]

[1] NOAA NCEI, Boulder, CO, United States
[2] CIRES, University of Colorado, Boulder, CO, United States

http://www.ngdc.noaa.gov/hazard
haz.info@noaa.gov

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Introduction

The **National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI)** is a data repository for high-resolution, integrated water-level data to support tsunami research, risk assessment and mitigation, to protect life and property damages along the coasts. **NCEI's** (formerly the **National Geophysical Data Center**) responsibilities include, but are not limited to processing, archiving and distributing deep-ocean and coastal water level data to isolate tsunami waves. High-resolution data for global historical tsunami events are collected by the **Deep-ocean Assessment and Reporting of Tsunami (DART®) tsunameter network** maintained by **NOAA's National Data Buoy Center (NDBC)**, coastal tide-gauges maintained by **NOAA's Center for Operational Oceanographic Products and Services (CO-OPS)** and the two **Tsunami Warning Centers**, historic marigrams and images, and bathymetric data from other national and international sources. NCEI water level database is developed in close collaboration with all data providers and with **NOAA's Pacific Marine Environmental Laboratory (PMEL)**. Our goal is to provide our customers with high-precision, homogeneous and "clean" records from data different sources and different sampling interval meeting their increasing needs for high quality data.

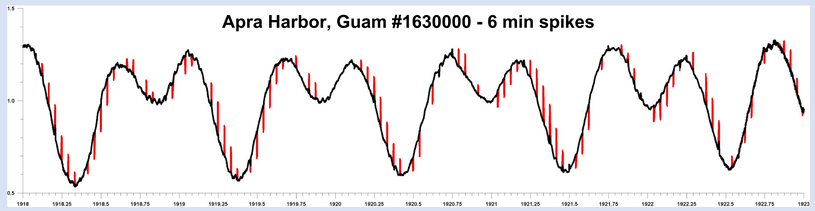
Present state in water-level data ingest and processing:

- DART® data, processed 235 records
- Bottom Pressure Recorder (BPR) data (pre-DART®), 98 processed records
- CO-OPS coastal tsunami tide-gauge stations, 222 sites
- National Tsunami Warning Center (NTWC), 9 tide stations
- Pacific Tsunami Warning Center (PTWC), 14 tide stations (under development)

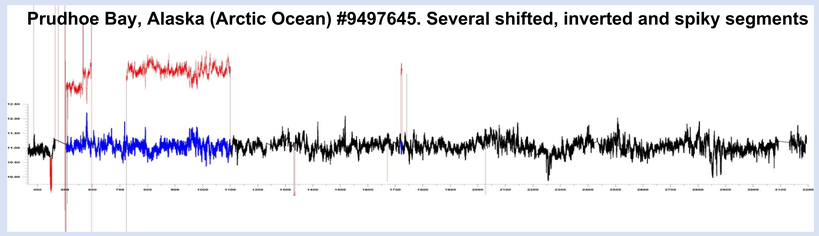
De-spiking – application of two level median filter

Advantages: highly customizable techniques against specific features of every one record and its segments. In every one case filter calibration is based on different lengths of the two consequent median filters and adjustable threshold against spikes' parameters. Spikes (outliers) are fixed only.

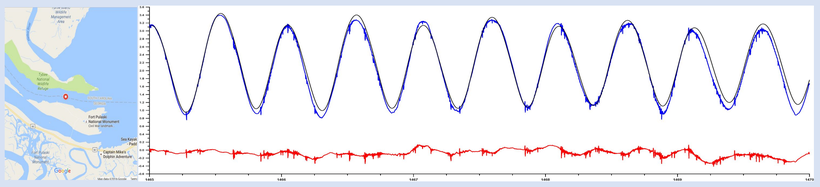
Apra Harbor, Guam #1630000 - 6 min spikes



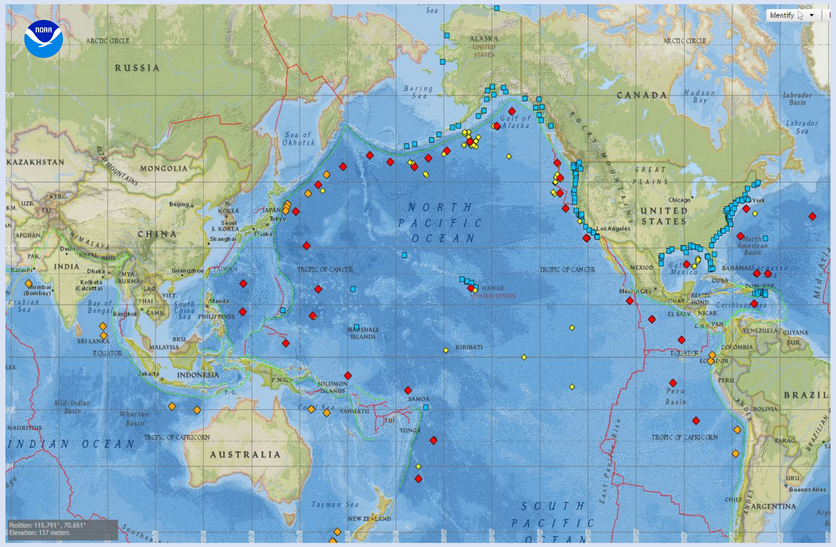
Prudhoe Bay, Alaska (Arctic Ocean) #9497645. Several shifted, inverted and spiky segments



Fort Pulaski #8670870 — impacted by the intensive navigation on Savannah Rive



NOAA Tsunami Observational Network



Data Access

DART® data https://www.ngdc.noaa.gov/hazard/dart

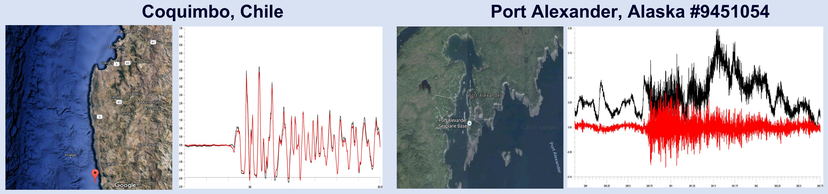
THREDDS water level data catalog:
https://www.ngdc.noaa.gov/thredds/enhancedCatalogWaterlevel.html

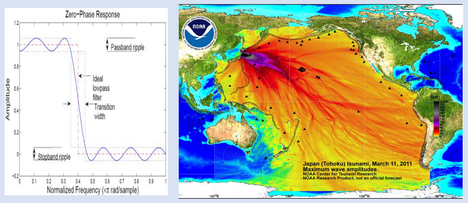
Filtering

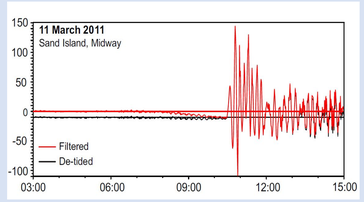
Usually digital filters cause distortion on the segment with the tsunami signal as shift in the mean water level, masking negative phase in the leading tsunami wave, decreasing the maximal and/or minimal water levels, etc. due to a leakage of energy from the two tidal bands. When tides are removed prior to filtering these effects are minimized.

Residuals from the tidal model (black lines) and from high-pass filtering (red lines) for the Chile 2015/09/16 event

Coquimbo, Chile | **Port Alexander, Alaska #9451054**







Acknowledgements

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Tidal Analysis

We apply customized version of the IOS harmonic tidal analysis package (Foreman *et al*, 2009).

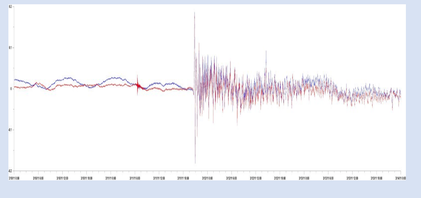
$h(t_j) = Z_0 + \sum f_k(t_j) \cdot A_k \cdot \cos[\, V_k(t_j) + u_k(t_j) - g_k \,] + R(t_j)$

$h(t_j)$ is the measurement $R(t_j)$ are the residuals at time t_j, $j=1,...,m$
Z_0 is the time-series' mean(mean water level)
A_k and g_k - are the amplitude and phase lag of constituent k, $k=1,...,n$
$f_k(t_j)$ – nodal corrections to the amplitude of constituent j at moment t_j
$u_k(t_j)$ – nodal corrections to the phase of constituent j at moment t_j
$V_k(t_j)$ – astronomical argument for tidal constituent k at moment t_j

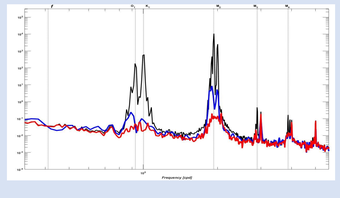
The corrections for the amplitudes and the phases of the tidal constituents and the astronomical argument are time dependent corresponding to the temporal variability of the tidal potential. The system is overdetermined as $m > 2 \cdot (n + 1)$ and is solved minimizing $\sum R^2(t_j)$ for $j=1,...,m$

Longer records provide opportunity to resolve more tidal constituents that could be extrapolated in temporal scales outside the measurement period.

Tohoku signal at DART® #43413 (360NM S of Acapulco, MX) based on short (blue) and longer (red) records



Spectra of raw data and residuals for DART® 52406,2013/08/18 – 20160714, blue line – residuals from 6 months record, red line – residuals from 48 months record



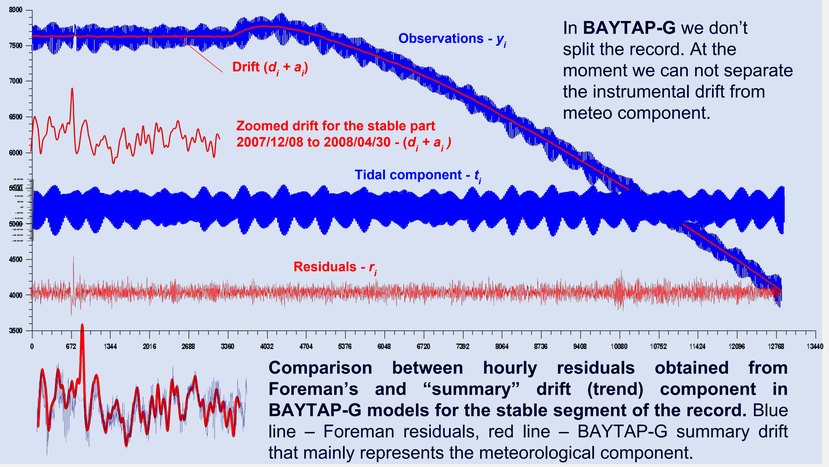
Application of BAYTAP-G

This program uses a Bayesian modeling procedure based on Akaike ABIC method to analyze time series that contain tidal and other variations – Tamura and Agnew (2016). Any time series y_i is considered as a combination of tidal component t_i, drift (trend) d_i with temporal correlation, offsets s_i with known times, component a_i correlated to another (auxiliary) time series that is usually a meteorological record, and uncorrelated residuals r_i.

$y_i = t_i + d_i + s_i + a_i + r_i$

If no auxiliary time series provided all correlated components (instrumental drift, meteorological effects, resonance, etc.) are included in the drift (trend).

DART® 46407 deployment 2007/12/08 to 2009/05/01 with sudden uplift and following downward trend. Because of the complex trend the record was split into two parts.



In **BAYTAP-G** we don't split the record. At the moment we can not separate the instrumental drift from meteo component.

Comparison between hourly residuals obtained from Foreman's and "summary" drift (trend) component in BAYTAP-G models for the stable segment of the record. Blue line – Foreman residuals, red line – BAYTAP-G summary drift that mainly represents the meteorological component.